Acta Botanica Brasilica, 2026, 40: e20250135
doi: https://doi.org/10.1590/1677-941X-ABB-2025-0135

Roots and fruits: Highlighting the BIPOC Botanists legacy

Original Article

Galls and Phytochemistry: a case study of Myrtaceae superhosts with emphasis on *Neomitranthes obscura*

Maria Alice Martins Ribeiro[1], Geraldo Luiz Gonçalves Soares[2], Bruno Garcia Ferreira[3], Caio Victor da Cruz Gomes[1], Ígor Abba Arriola[1], Rosy Mary dos Santos Isaias[1,*]

[1] Universidade Federal de Minas Gerais, Instituto de Ciências Biológicas, Departamento de Botânica, Belo Horizonte, MG, Brazil.
[2] Universidade Federal do Rio Grande do Sul, Instituto de Biociências, Laboratório de Evolução, Ecologia Química e Quimiotaxonomia, Porto Alegre, RS, Brazil
[3] Universidade Federal do Rio de Janeiro, Instituto de Biologia, Departamento de Botânica, Rio de Janeiro, RJ, Brazil
*Corresponding author: rosy-isaias@ufmg.br

ABSTRACT

The Myrtaceae is rich in phenolics and volatile terpenoids and has many reported associations with gall inducers in Brazilian *restinga*. These metabolites protect plants against both biotic and abiotic stresses, but also play a crucial signaling role in plant-herbivore interactions, especially on superhosts like *Neomitranthes obscura*. We hypothesize that the chemical identity of the superhosts relates to their capacity to respond to diverse galling herbivores, which was assessed through a two-step bibliographic survey resulting in 52 analysed documents. The prevalent classes of chemical compounds in the superhost Myrtaceae are hydrocarbonated (SH) and oxygenated sesquiterpenes (OS), which are related to plant identity and its interactions with the galling organisms. Among the superhost Myrtaceae, *Neomitranthes obscura* shares sesquiterpenic and phenolic derivatives with other host plants, which makes it impossible to infer why some species are superhosts while others are not. Our results suggest that a greater diversity of terpenoids may be related to metabolic flexibility, potentially increasing the ability of hosting galling species. However, further research is needed to explore this relationship, particularly in conjunction with other key metabolite classes in Myrtaceae, such as phenolic compounds.

Keywords: Galls, Monoterpenes, Plant-insect interactions, Sesquiterpenes, Terpenoid profile.

Received July 30, 2024; Accepted January 22, 2026
Editor-in-Chief: Thaís Elias Almeida; Associate Editor: Anderson Ferreira Pinto Machado

How to cite:
Ribeiro MAM, Soares GLG, Ferreira BG, Gomes CVC, Arriola IA, Isaias RMS. 2026. Galls and Phytochemistry: a case study of Myrtaceae superhosts with emphasis on *Neomitranthes obscura*. Acta Botanica Brasilica 40: e20250135. doi: 10.1590/1677-941X-ABB-2025-0135

Introduction

The secondary metabolites can influence the association of plants with herbivores, such as gall inducers, through both attraction and repellence (Hall *et al.*, 2017; Divekar *et al.*, 2022). For some plant families, such as Myrtaceae, the second-largest family of the Atlantic Forest (Stehmann *et al.*, 2009), the chemical diversity of compounds may be related to the richness and diversity of associated gall inducers (Hall *et al.*, 2017). The diversity of plant-herbivore associations is often linked to host species richness (Maia *et al.*, 2014; Grandez-Rios *et al.*, 2024). Therefore, we focused on the Myrtaceae, one of the most species-rich families in the Brazilian restinga, to study galling herbivore superhosts (Souza & Morim, 2008; Lourenço & Barbosa, 2012; Maia, 2019). The largest and most diverse genera of Myrtaceae in the Neotropical region are *Eugenia* L., *Myrcia* DC., and *Psidium* L. (Mabberley, 1997; Rosario *et al.*, 2005; Martins *et al.*, 2008; Giaretta & Peixoto, 2015; Govaerts *et al.*, 2019), which are also rich in interactions with galling insects (Maia, 2019).

The attractiveness and repellence of these insects may be related to the accumulation of essential oils, steroids, and phenolic compounds, including flavonoids and tannins, which are common in Myrtaceae (Ramirez *et al.*, 2012; Girardelo *et al.*, 2020). Among the chemical classes of lipidic substances in Myrtaceae, terpenes constitute a broad class of metabolites that play a crucial role in plant ecological interactions, particularly in adapting to abiotic and biotic stresses, including associations with herbivores and pathogens (Victório *et al.*, 2018; Toffolatti *et al.*, 2021). Volatile terpenes, such as mono- and sesquiterpenes, can play a prominent role in signaling insect-plant interactions in very specific ways (Holopainen *et al.*, 2013; Naidoo *et al.*, 2018). For example, the concentration of certain monoterpenes determines species selection in Apiaceae by psyllid species (Homoptera: Psyllidae) (Valterová *et al.*, 1997). One example of a complex phenomenon modulated by these substances involves β-caryophyllene, which is produced by the flowers of several plant species and functions as an alarm pheromone for aphids (Holopainen *et al.*, 2013). The volatile compounds produced by galls are also related to the defense of gall-inducers against browsing mammals (Rostás *et al.*, 2013), acting as possible deterrents of the natural enemies of gall inducers. On the other hand, they can be synthesized by host plants and attract parasitoids of the gall inducers, a role yet understudied (Borges, 2018).

The terpenoid profile in Myrtaceae, especially in its most diverse genera – *Myrcia, Eugenia,* and *Psidium* (Amorim & Alves, 2012) – reveals a predominance of flavonoids, mono- and sesquiterpenes (Saber *et al.*, 2023; Keszei *et al.*, 2010). The genus *Eugenia* is rich in flavonoids such as quercetin, myricetin, and kaempferol, tannins, chalcones, and monoterpene hydrocarbons such as α-pinene, β-pinene, and linalool (Oliveira AMD *et al.*, 2006; Pino *et al.*, 2005; Queiroz *et al.*, 2015; Ribeiro *et al.*, 2016; Silva PR *et al.*, 2021). Flavonoids comprise one of the most diverse groups of natural products, with 9,000 different structures discovered to date, and diverse functions, including UV protection and signaling events (Papoutsis *et al.*, 2021). The genus *Myrcia* is also rich in flavonoids such as myricetin, phenolic acids, and sesquiterpene hydrocarbons such as ε-caryophyllene, δ-cadinene, and caryophyllene oxide (Ferreira *et al.*, 2006; Stefanello *et al.*, 2010; Pereira-Júnior, 2018; Araújo *et al.*, 2020). Sesquiterpenes occur as hydrocarbons or in oxygenated forms, including essential oils and aromatic constituents with pharmacological activities, for example (Papoutsis *et al.*, 2021). In several species of *Psidium*, the major compounds identified are sesquiterpene hydrocarbons (Pino *et al.*, 2003; Padovan *et al.*, 2014; Santos *et al.*, 2022). Sesquiterpenes are mostly liquid and are mainly found in the volatile oils of plants, and their oxygen-containing derivatives are also widely found in volatile oils (Yang *et al.*, 2021).

The chemical diversity of Myrtaceae is, in most cases, related to evolutionary factors and abiotic and biotic pressures, such as an arms race against herbivores, including specialists like the gall inducers (Padovan *et al.*, 2014; Maia, 2019; Martins *et al.*, 2023). These plant-insect interactions are responsible for structural and metabolic alterations in host plant cells and tissues, leading to gall development (Oliveira *et al.*, 2016). At the structural level, gall inducers promote changes such as hyperplasia, cell hypertrophy, tissue homogenization, neoformation of vascular tissues, and redifferentiation of specialized tissues at the gall developmental site (Ferreira *et al.*, 2019). Host plants may be associated with one or more inducers, comprising the superhosts (Isaias *et al.*, 2013), which reflect the diversity of morphogenetic pathways and, consequently, changes in the biosynthesis of secondary metabolites (Oliveira DC *et al.*, 2006; Guedes *et al.*, 2016, 2023; Jorge *et al.*, 2018), which are crucial for the understanding of these interactions. In general, phenolic derivatives are strongly associated with plant defenses against oxidative stresses (Isaias *et al.*, 2015) but may also play a crucial role in hormonal regulation (Bedetti *et al.*, 2017; 2018). While free-living herbivores can be harmed by astringent and antinutritional phenolics, the role of these phenolic compounds as signals for oviposition by galling insects has been observed (Roininen *et al.*, 1999), and they can also be detected in gall tissue compartments, such as the nutritive tissue promoting the disponibilization of specific nutrients (Isaias *et al.*, 2018; Arriola *et al.*, 2024; Souza *et al.*, 2024).

As expected, due to the chemical diversity of Myrtaceae, the terpenoid profile of the superhost species can vary in quantity and quality. In *Myrcia splendens* (SW.) DC., there was a decrease in the amount of δ-muurolene, β-elemene, and α-caryophyllene after the removal of *Nexothrips* sp. individuals from leaf-rolling galls (Jorge *et al.*, 2018), indicating the suppression or neo-synthesis of compounds

due to the stimuli of the gall inducers. By investigating the literature on the terpenoid profile of Myrtaceae, which are superhosts of galls in Brazilian *restingas*, we aim to verify if the species have chemical similarities related to their capacity to attract and respond to diverse galling herbivores. Accordingly, we may identify peculiarities related to species-specific gall morphotypes, using as a case study the superhost Myrtaceae *Neomitranthes obscura* (DC.) N.Silveira, which bears six distinct gall morphospecies, is abundant on the sandy coastal plains of Southeast Brazil and is rich in lipophilic terpenoids.

Materials and Methods

The study was carried out in two steps: the first step involved a search for superhost species of Myrtaceae in the *restinga* biome, using Google Scholar from January to June 2025. This search resulted in 16 species: *Eugenia astringens* Cambess., *E. copacabanensis* Kiaersk, *E. hiemalis* Cambess., *E. punicifolia* (Kunth) DC., *E. speciosa* Cambess., *E. sulcata* Spring ex Mart., *E. uniflora* L., *Myrcia amazonica* DC., *M. brasiliensis* Kiaersk, *M. ovata* Cambess., *M. palustris* DC., *M. splendens* (SW.) DC., *Myrciaria floribunda* (West ex Willdenow) Berg, *Neomitranthes obscura* (DC.) N. Silveira, *Plinia peruviana* (Poir.) Govaerts, and *Psidium cattleyanum* Sabine, as reported in Maia (2013) and Maia (2019).

The second step was the association of the species names with the terms "chemical profile", "phytochemical profile", and "phytochemical studies", and the corresponding terms in Portuguese ("*perfis químicos*", "*perfis fitoquímicos*", and "*estudos fitoquímicos*"), both in Google Scholar and Web of Science (Fig. 1). The synonyms of *E. astringens*, *E. hiemalis*, *E. punicifolia*, *M. amazonica*, *M. brasiliensis*, *M. palustris*, *M. splendens*, *P. peruviana,* and *P. cattleyanum* were included in the search (Table 1). The accepted names for the Myrtaceae species were chosen in accordance with Flora e Funga do Brasil (2025). These two steps were summarized in a flowchart (Fig. 1). No time range was applied to the articles, book chapters, dissertations, and theses. An additional step was the analysis of the papers to identify their approaches. We include neither the methodological procedures for metabolite extraction nor the papers with no details of the chemical compounds. The data related to the more abundant secondary metabolites, terpenes, and phenolic compounds were compiled (Table 1).

We used usual biodiversity measures to convert the multiple variables into intuitive and straightforward data (Boulet *et al.*, 2010; Hilker, 2014) to evaluate the diversity profiles of four chemical subclasses (monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes). The diversity index of chemical subclasses (DCQ) was calculated for each chemical class based on its species profile. The DCQ index was calculated by the Shannon-Wiener formula ($-\Sigma\, pi \times \ln pi$), where *pi* represents the richness proportion of a class concerning the total richness of the species (Table 2). As direct biological interpretation is not possible (Jost, 2006), we calculated the true diversity index (DV) from the exponential chemical diversity index (e^DCQ). This index quantifies the number of chemical subclasses effectively present in each species, allowing a more intuitive comparison of the magnitude of the differences among species (Chao *et al.*, 2014). The diversity analyses were performed in PAST – Paleontological Statistics Software Package (Hammer *et al.*, 2001). To compare and visualize the distribution

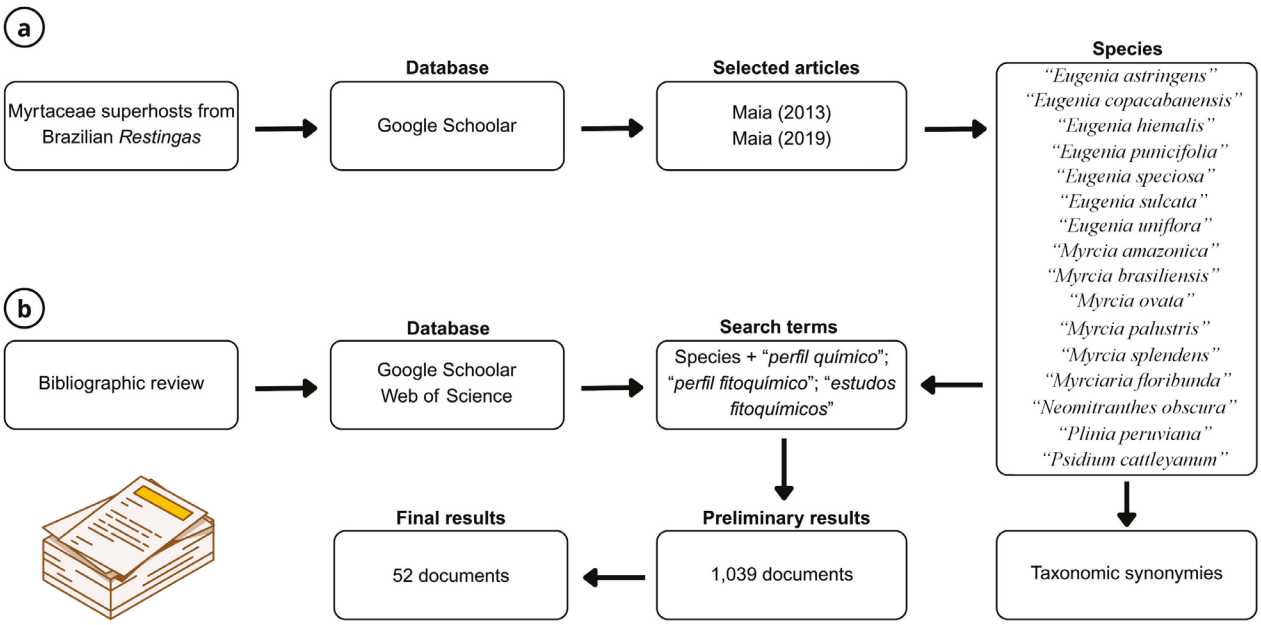

Figure 1. Flowchart of the steps employed in the literature review.

Table 1. Superhost Myrtaceae of Brazilian *restingas* with information on their associated gall inducers, morphotypes, chemical compounds, and biological activity

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Eugenia astringens Cambess. /= *E. umbelliflora* O. Berg, *E. rotundifolia* Casar	**1.** Marginal roll, green, glabrous, one-chambered **2.** Bud, cylindrical, brown, glabrous, one-chambered **3.** Lenticular, yellow, glabrous, one-chambered **4.** Conical **5.** Conical. **6.** Claviform, reddish, glabrous, one-chambered **7.** Stem, fusiform. **8**. Globoid, green, glabrous, one-chambered **9.** Lenticular, green, glabrous, one-chambered	**1.** *Dasineura marginalis* Maia, 2005 (Cecidomyiidae, Diptera) **2.** *Stephomyia rotundifoliorum* Maia, 1993 (Cecidomyiidae) **3.** *Dasineura globosa* Maia, 1995. (Cecidomyiidae) **5.** Cecidomyiidae **6.** *Stephomyia clavata* (Tavares 1920) (Cecidomyiidae) **7.** Undetermined **8**. Undetermined **9.** *Jorgenseniella eugeniae* Maia, 2005 (Cecidomyiidae)	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; (E)-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; globulol; α-copaene; α-cubebene; α-muurolol; limonene; viridiflorene; viridiflorol; aromadendrene	Astringents and Antioxidant activity	Leaves and Buds	–	Apel *et al.* (2002); Magina *et al.* (2009); Ramos *et al.* (2010); Defaveri *et al.* (2011); Silva TD *et al.* (2021); Pinto *et al.* (2022)
Eugenia copacabanensis Kiaersk /-	**1.**Spiraled, reddish, glabrous, one-chambered. **2.** Bud, conical, green, glabrous, pedunculated. **3.** Leaf roll, reddish, glabrous, one-chambered. **4.** Leaf gall **5.** Stem gall **6.** Stem gall **7.** Fusiform, reddish, glabrous, one-chambered. **8.** Conical, reddish, glabrous, one-chambered **9.** Lenticular, green, glabrous, one-chambered. **10.** Marginal roll, green, glabrous, one-chambered. **11.** Globoid, green, glabrous, one-chambered. **12.** Bud, rosette, green, glabrous, one-chambered. Galler: Undetermined	**1.** *Stephomyia espiralis* Maia, 1993 (Cecidomyiidae) **2.** *Dasineura copacabanensis* Maia, 1993 (Cecidomyiidae) **3.** *Dasineura* sp. (Cecidomyiidae) **4.** Cecidomyiidae **5.** Cecidomyiidae **6.** Hymenoptera **7.** *Stephomyia tetraloba* Maia, 1993 (Cecidomyiidae) **8.** *Bruggmannia* sp. (Cecidomyiidae) **9.** Undetermined **10.** Undetermined **11.** Hymenoptera **12.** Undetermined	α-pinene; β-pinene; α-humulene; allo-aromadendrene; caryophyllene oxide; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; α-muurolol; viridiflorol, aromadendrene; γ-elemene	Antioxidant activity	Leaves, buds, and stems	Quercetin	Nakamura *et al.* (2010); Arruda & Victório (2011); Carvalho-Junior *et al.* (2014)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Eugenia hiemalis Cambess. /= *E. hyemalis* Cambess.	**1.** Bud, cylindrical, brown, glabrous, one-chambered. **2.** Lenticular, green, glabrous, one-chambered. **3.** Marginal roll, green, glabrous, one-chambered. **4.** Conical, yellow, glabrous, one-chambered. **5.** Claviform, green or reddish, glabrous, one-chambered **6.** Conical, yellow, glabrous, one-chambered. Galler: Cecidomyiidae	**1.** *Stephomyia* sp. (Cecidomyiidae) **2.** Lasiopteridi (Cecidomyiidae) **3.** Cecidomyiidae **4.** Cecidomyiidae **5.** *Stephomyia* cfr. *clavata* (Tavares, 1920) (Cecidomyiidae) **6**: Cecidomyiidae	α-humulene; allo-aromadendrene; β-caryophyllene; β-selinene; γ-cadinene; α-cadinol; germacrene D; α-copaene; α-cubebene; α-muurolene; α-muurolol; aromadendrene; δ-cadinene	Amoebicide activity	Leaves and stem	Quercitrin	Apel *et al.* (2004); Bokesch *et al.* (2008); Zatelli (2015)
Eugenia punicifolia (Kunth) DC. /= *E. ovalifolia* Camb.	**1.** Cylindrical, green or reddish, glabrous, one-chambered. **2.** Lenticular, green, glabrous, one-chambered. **3.** Leaf Gall **4.** Fusiform, brown, glabrous, multichambered. **5.** Stem gall **6.** Stem gall on stem. **7.** Fruit, globoid, green or yellow, glabrous, multichambered. **8.** Fruit gall	**1.** *Stephomyia* sp. (Cecidomyiidae) **2.** Cecidomyiidae **3.** Cecidomyiidae **4.** Lasiopteridi (Diptera, Cecidomyiidae) **5**. Hymenoptera **6.** Undetermined **7.** Undetermined **8.** Cecidomyiidae	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; β-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; α-muurolene; α-muurolol; limonene; viridiflorene; viridiflorol; linalool; aromadendrene; γ-elemene; δ-cadinene	Antioxidant activity	Leaves, stems, and fruits	Quercetin; quercitrin; myricetin; myricitrin; gallic acid;	Maia *et al.* (1997); Godoy *et al.* (1999); de Oliveira *et al.* (2005); Pereira *et al.* (2010); Ramos *et al.* (2010); Neves *et al.* (2024)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Eugenia speciosa Cambess. /-	**1.** Conical, yellow, glabrous, one-chambered **2.** Claviform, green, glabrous, one-chambered	**1.** *Schizomyiina* (Cecidomyiidae) **2.** *Schizomyiina* (Cecidomyiidae)	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; β-caryophyllene; globulol; limonene; viridiflorol; linalool; aromadendrene; δ-cadinene	-	Leaves	–	Alves *et al.* (2000); Apel *et al.* (2004)
Eugenia sulcata Spring ex Mart. /-	**1.** Bud, cylindrical, reddish, glabrous, one-chambered. **2.** Bud, ovoid, green, glabrous. Galler: Undetermined	**1.** Undetermined **2.** Undetermined	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; β-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; limonene; viridiflorol; linalool	Antimicrobial activity	Leaves and buds	–	Apel *et al.* (2004) Ramos *et al.* (2010); Lima *et al.* (2012); da Silva *et al.* (2024)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Eugenia uniflora L. /-	**1.** Globoid, spongy, whitish, glabrous, one-chambered. **2.** Conical, green or reddish, glabrous, one-chambered. **3.** Lenticular, green, yellowish or black, glabrous, one-chambered. **4.** Fruit, conical, reddish, glabrous, one-chambered. Galler: Cecidomyiidae **5.** Conical, green, glabrous, one-chambered. **6.** Bud flower, conical, reddish, glabrous, one-chambered. **7.** Stem, fusiform, brown, glabrous, one-chambered. **8.** Fold, green, glabrous, one-chambered.	**1.** *Maiamyia dispar* Maia, Mendonça & Romanovski, 1997, comb. nov. (*Eugeniamyia*) (Cecidomyiidae) **2.** *Clinodiplosis profusa* Maia, 2001 (Cecidomyiidae) **3.** *Neolasioptera eugeniae* Maia, 1993 (Cecidomyiidae) **4.** Cecidomyiidae **5.** *Maiamyia triangularis* Maia & Nava, 2011 comb. nov. (*Eugeniamyia*) (Cecidomyiidae) **6.** Cecidomyiidae **7.** Undetermined **8.** Cecidomyiidae	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-cubebene; limonene; viridiflorene; viridiflorol; linalool; aromadendrene; γ-elemene; δ-cadinene	Antimicrobial, antihyperglycemic, antypertriglyceridemia, anti-inflammatory, digestive, and hypotensive	Leaves, fruits, and stems	Quercetin; quercitrin; myricetin; myricitrin; gallic acid	Melo *et al.* (2007); Marin *et al.* (2008); Rodrigues *et al.* (2013); Santos *et al.* (2015); Mesquita *et al.* (2017); dos Santos *et al.* (2018); Silva TD *et al.* (2021);
Myrcia amazonica DC. /= *M. lundiana* Kiaersk	**1.** Globoid gall **2.** Leaf gall **3.** Bud ovoid, grooved. **4.** Fusiform gall on flower peduncle **5.** Leaf lenticular. **6.** Leaf gall on vein.	**1.** *Dasineura* sp. (Cecidomyiidae) **2.** Undetermined **3.** *Myrciamyia maricaensis* Maia, 1995 (Cecidomyiidae) **4.** Cecidomyiidae **5.** Undetermined **6.** Undetermined	α-pinene; β-pinene; α-terpineol; α-humulene; caryophyllene oxide; (E)-caryophyllene; β-selinene; α-selinene; limonene; linalool	Antifungal activity	Leaves	–	Alves *et al.* (2016); Melo *et al.* (2021)
Myrcia brasiliensis Kiaersk /= *Gomidesia schaueriana* O. Berg	**1.** Stem gall, fusiform, brown, glabrous, one-chambered. **2.** Bud ovoid gall, multichambered, glabrous.	**1.** *Pacholenus pelliceus* Boheman, 1836 (Coleoptera: Curculionidae) **2.** Undetermined	α-pinene; β-pinene; allo-aromadendrene; caryophyllene oxide; β-selinene; germacrene D; limonene; viridiflorol; γ-elemene	Antifungal activity	Leaves	–	Limberger *et al.* (2003); Pansera *et al.* (2021)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Myrcia ovata Cambess. /-	**1.** Globoid, yellow, glabrous, one-chambered. **2.** Leaf gall **3.** Ovoid, bud, green, grooved, glabrous, one-chambered. **4.** Fusiform on flower peduncle, green, glabrous, one-chambered. **5.** Conical, green, glabrous, one-chambered. **6.** Conical, green, glabrous, one-chambered. **7.** Marginal roll, green, glabrous, one-chambered. **8.** Lenticular, green, glabrous, one-chambered.	**1.** *Dasineura* sp. (Cecidomyiidae) **2.** Undetermined **3.** *Myrciamyia maricaensis* Maia, 1995 (Cecidomyiidae) **4.** Cecidomyiidae **5.** *Dasineura* sp. (Cecidomyiidae) **6.** Cecidomyiidae **7.** Thysanoptera **8.** Undetermined	α-pinene; β-pinene; α-terpineol; caryophyllene oxide; E-caryophyllene; β-selinene; α-selinene; linalool	Antibacterial, antibiofilm, fungicidal and anti-inflammatory activity	Leaves	–	Cândido *et al.* (2010); Lima *et al.* (2011); Jesus *et al.* (2016); Amorim *et al.* (2021)
Myrcia palustris DC. /= *Gomidesia palustris* (DS.) Kausel	**1.** Lenticular, green, glabrous, one-chambered. **2.** Bud, ovoid gall, brown, glabrous, multichambered.	**1.** Undetermined **2.** Undetermined	α-humulene; caryophyllene oxide; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; α-muurolene; viridiflorene; aromadendrene; δ-cadinene	Formicidal and antimicrobial	Leaves	–	Limberger *et al.* (2003); Santos *et al.* (2021)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Myrcia splendens (SW.) DC. /= *M. fallax* (Rich.) DC.	**1.** Globoid, green, glabrous, one-chambered. **2.** Conical, yellow or green, glabrous, one-chambered. **3.** Marginal roll, green, glabrous, one-chambered. **4.** Leaf roll, reddish, glabrous, one-chambered. **5.** Bud globoid, green or brown, glabrous, multichambered. **6.** Globoid, brown, glabrous. **7.** Globoid, brown, glabrous, one-chambered. **8.** Bud gall. **9.** Stem, fusiform, multichambered. **10.** Stem or leaf vein. **11.** Bud conical.	**1.** Undetermined **2.** Undetermined **3.** Undetermined **4.** Undetermined **5.** Undetermined **6.** Lasiopteridi (Cecidomyiidae) **7.** Lasiopteridi (Cecidomyiidae) **8.** Lasiopteridi (Cecidomyiidae) **9.** Cecidomyiidae **10.** Lasiopteridi (Cecidomyiidae) **11.** Undetermined	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; β-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; α-muurolene; α-muurolol; limonene; viridiflorene; viridiflorol; linalool; aromadendrene; γ-elemene; δ-cadinene	Antioxidant and antifungal activity	Leaves	Quercitrin; myricitrin; myricetin; gallic acid	Cole *et al.* (2008); Nakamura *et al.* (2010); Pereira *et al.* (2010); Guldbrandsen *et al.* (2014); Jorge *et al.* (2018); Montalvão *et al.* (2023)
Myrciaria floribunda (West ex Willdenow) Berg /-	**1.** Globoid, green, glabrous, one-chambered. **2.** Conical, yellow or green, glabrous, one-chambered. **3.** Marginal roll, green, glabrous, one-chambered. **4.** Leaf roll, reddish, glabrous, one-chambered. **5.** Globoid, green or brown, glabrous, multichambered. **6.** Globoid, brown, glabrous.	**1.** Undetermined **2.** Undetermined **3.** Undetermined **4.** Undetermined **5.** Undetermined **6.** Lasiopteridi (Cecidomyiidae) **7.** Lasiopteridi (Cecidomyiidae) **8.** Lasiopteridi (Cecidomyiidae)	α-pinene; α-terpineol; α-humulene; allo-aromadendrene; E-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D;	Anti-inflammatory activity	Leaves and fruits	Gallic acid	Ramos *et al.* (2010); de Oliveira *et al.* (2018); García *et al.* (2021); García *et al.* (2022); Dos Santos de Moraes *et al.* (2023);

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Myrciaria floribunda (West ex Willdenow) Berg /-	**7.** Globoid brown, glabrous, one-chambered. **8.** Gall on bud. **9.** Stem, fusiform, multichambered. **10.** Stem or leaf vein. **11.** Bud, conical.	**9.** Cecidomyiidae **10.** Lasiopteridi (Cecidomyiidae) **11.** Undetermined	globulol; α-copaene; α-cubebene; α-muurolene; α-muurolol; viridiflorene; viridiflorol; aromadendrene; γ-elemene; δ-cadinene				
Neomitranthes obscura (DC.) N. Silveira /-	**1.** Conical, green, glabrous, one-chambered. **2.** Leaf roll, green, glabrous, one-chambered. **3.** Fusiform, green, glabrous, one-chambered. **4.** Roll marginal, green, glabrous, one-chambered. **5.** Pineapple-shaped, green, glabrous. **6.** Fusiform, brown, glabrous, one-chambered.	**1.** Cecidomyiidae **2.** *Thysanoptera* **3.** *Stephomyia mina* Maia, 1993 (Cecidomyiidae) **4.** *Clinodiplosis* sp. (Cecidomyiidae) **5.** *Neomitranthella robusta* Maia, 1995 (Cecidomyiidae) **6.** Undetermined	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; E-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; germacrene D; globulol; α-copaene; α-cubebene; α-muurolene; α-muurolol; limonene; linalool; aromadendrene; γ-elemene; δ-cadinene	–	Leaves, stem, and fruits	Delphinidin-3-O-glucoside; cyanidin-3-O-glucoside	Ramos *et al.*(2010); Amaral *et al.* (2013); Gouvêa *et al.* (2015); Victório *et al.* (2018)

Table 1. Cont.

Plant Species/Synonyms	Gall morphotypes according to Maia VC (2019)	Inducers	Most abundant monoterpenes and sesquiterpenes	Biological activity	Organ	Most abundant phenolic compounds	References
Plinia peruviana (Poir.) Govaerts /= *P. cauliflora* (Mart.) Kausel, *Myrciaria jaboticaba* (Vell.) O. Berg	**1.** Marginal roll, green, glabrous, one-chambered. **2.** Cylindrical, green, glabrous, one-chambered.	**1.** Cecidomyiidae **2.** Cecidomyiidae	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; β-caryophyllene; α-cubebene; linalool; aromadendrene; δ-cadinene	Healing and antioxidant activity	Leaves and fruits	Quercetin; quercitrin; myricetin; myricitrin; gallic acid; delphinidin-3-glucoside; cyanidin-3-O-glucoside;	da Silva *et al.* (2019); Inada *et al.* (2018); Almeida *et al.* (2025)
Psidium cattleyanum Sabine /= *P. cattleianum* Sabine	**1.** Biconical, green, glabrous, one-chambered. **2.** Globoid, yellow, glabrous, one-chambered. **3.** Fusiform, brown, glabrous, multichambered. **4.** Tubular, green, glabrous, one-chambered. **5.** Rosette green, glabrous. **6.** Conical, with small apical projections, green, glabrous. **7.** Globoid, one-chambered. **8.** Lenticular.	**1.** *Tectococcus ovatus* Hempel (Eriococcidae, Hemiptera) **2.** Cecidomyiidae **3.** Undetermined **4.** Lasiopteridi (Cecidomyiidae) **5.** *Dasineura gigantea* Angelo & Maia, 1999 (Cecidomyiidae) **6.** Cecidomyiidae **7.** Undetermined **8.** Cecidomyiidae	α-pinene; β-pinene; α-terpineol; α-humulene; allo-aromadendrene; caryophyllene oxide; β-caryophyllene; β-selinene; α-selinene; γ-cadinene; α-cadinol; globulol; α-copaene; α-muurolene; α-muurolol; limonene; viridiflorol; linalool; aromadendrene; δ-cadinene	Anti-inflammatory and antioxidant activity	Leaves, stems, and buds	Quercetin; quercitrin; myricetin; gallic acid; cyanidin-3-O-glucoside	Marin *et al.* (2008); Adam *et al.*(2011); Silva TD *et al.* (2021); El-Deeb *et al.* (2024)

patterns of the most abundant volatile compounds, a presence/absence matrix was generated. Regarding the distribution of total volatile compounds, the data were quantified and characterized into chemical subclasses. A heatmap was generated using the *vegan* (Oksanen *et al.*, 2022) and *pheatmap* (Kolde, 2019) packages in R Studio (Posit Team, 2025).

For phenolic compounds, we performed a histochemical analysis of metabolite distribution on leaves, non-galled buds, and mature galls induced on *N. obscura* by the following Cecidomyiidae (Diptera): the marginal leaf-rolling galls induced by *Dasineura tavaresi* Maia, 1995; the clavate and lenticular leaf galls induced by unidentified cecidomyiids, and rosette galls induced on buds by *Neomitranthella robusta* Maia, 1995 (Maia, 2024). Samples of ungalled organs and galls (n = 5) were collected in the Maricá *restinga*, Rio de Janeiro state, Brazil (22°57'39.1" S; 42°50'45.8" W). The samples were fixed in 2.5 % glutaraldehyde and 4.5 % formaldehyde in 0.1 M phosphate buffer, pH 7.2 (Karnovsky, 1965) and sectioned using razor blades and submitted to 10 % ferric chloride for 5 minutes (Johansen, 1940). The slides were mounted in distilled water, observed, and photographed under a light microscope (Leica® DM2500) with a coupled digital camera (Leica® DFC7000 T).

Results

The most abundant chemical compounds per species

Thinking about the extremes in terms of gall morphotypes, the 16 species of Myrtaceae that serve as superhosts for galling herbivores are rich in secondary metabolites (Table 1), with sesquiterpene hydrocarbons as the major chemical class. Among these chemical subclasses, the β-selinene was the most common chemical compound, reported for 13 species. The distribution of the other most abundant compounds among the species is shown in Figure 2.

The diversity of chemical subclasses

The chemical compounds of the Myrtaceae are distributed into monoterpene hydrocarbons (MH), oxygenated monoterpenes (OM), sesquiterpene hydrocarbons (SH), and oxygenated sesquiterpenes (OS) (Table 2). Regarding the richness distribution among the chemical subclasses, *M. brasiliensis* (3.81), *E. copacabanensis* (3.71), *E. astringens* (3.68), and *E. speciosa* (3.61) have a well-distributed chemical profile (DV > 3.6). *Eugenia hiemalis* (2.17) and *M. palustris* (2.22)

Table 2. Distribution of chemical compounds among monoterpene hydrocarbons (MH), oxygenated monoterpenes (OM), sesquiterpene hydrocarbons (SH), and oxygenated sesquiterpenes (OS).

Species	Richness (Total terpenes)	Proportion in % of terpene classes				DCQ	DV
		MH	OM	SH	OS		
Eugenia astringens	110	17 (15.4 %)	15 (13.6 %)	44 (40 %)	34 (31 %)	1.30	3.68
Eugenia copacabanensis	53	4 (7.5 %)	17 (32 %)	15 (28.3 %)	17 (32 %)	1.31	3.71
Eugenia hiemalis	46	1 (2.1 %)	0 (0 %)	28 (60.8 %)	17 (37 %)	0.78	2.17
Eugenia punicifolia	95	14 (14.7 %)	8 (8.4 %)	48 (50.5 %)	25 (26.3 %)	1.20	3.33
Eugenia speciosa	59	25 (42.3 %)	6 (10.1 %)	18 (30.5 %)	10 (17 %)	1.29	3.61
Eugenia sulcata	64	10 (15.6 %)	4 (6.25 %)	26 (40.6 %)	24 (37.5 %)	1.22	3.39
Eugenia uniflora	70	8 (11.4 %)	2 (2.8 %)	30 (42.8 %)	30 (42.8 %)	1.10	3.00
Myrcia amazonica	45	10 (22.2 %)	26 (57.7 %)	5 (11.1 %)	4 (8.8 %)	1.14	3.14
Myrcia brasiliensis	56	6 (10.7 %)	14 (25 %)	20 (35.7 %)	16 (28.5 %)	1.34	3.81
Myrcia ovata	30	3 (10 %)	17 (56.6 %)	4 (13.3 %)	6 (20 %)	1.19	3.30
Myrcia palustris	45	1 (2.2 %)	0 (0 %)	25 (55.5 %)	19 (42.2 %)	0.80	2.22
Myrcia splendens	80	7 (8.7 %)	7 (8.7 %)	39 (48.7 %)	27 (33.7 %)	1.16	3.20
Myrciaria floribunda	120	17 (14.1 %)	23 (19.1 %)	60 (50 %)	20 (16.67 %)	1.25	3.49
Neomitranthes obscura	102	8 (7.8 %)	14 (13.7 %)	45 (44.1 %)	35 (34.3 %)	1.22	3.37
Plinia peruviana	21	6 (28.5 %)	3 (14.2 %)	11 (52.3 %)	1 (4.7 %)	1.19	3.29
Psidium cattleyanum	64	12 (18.7 %)	6 (9.3 %)	29 (45.3 %)	17 (26.5 %)	1.25	3.48

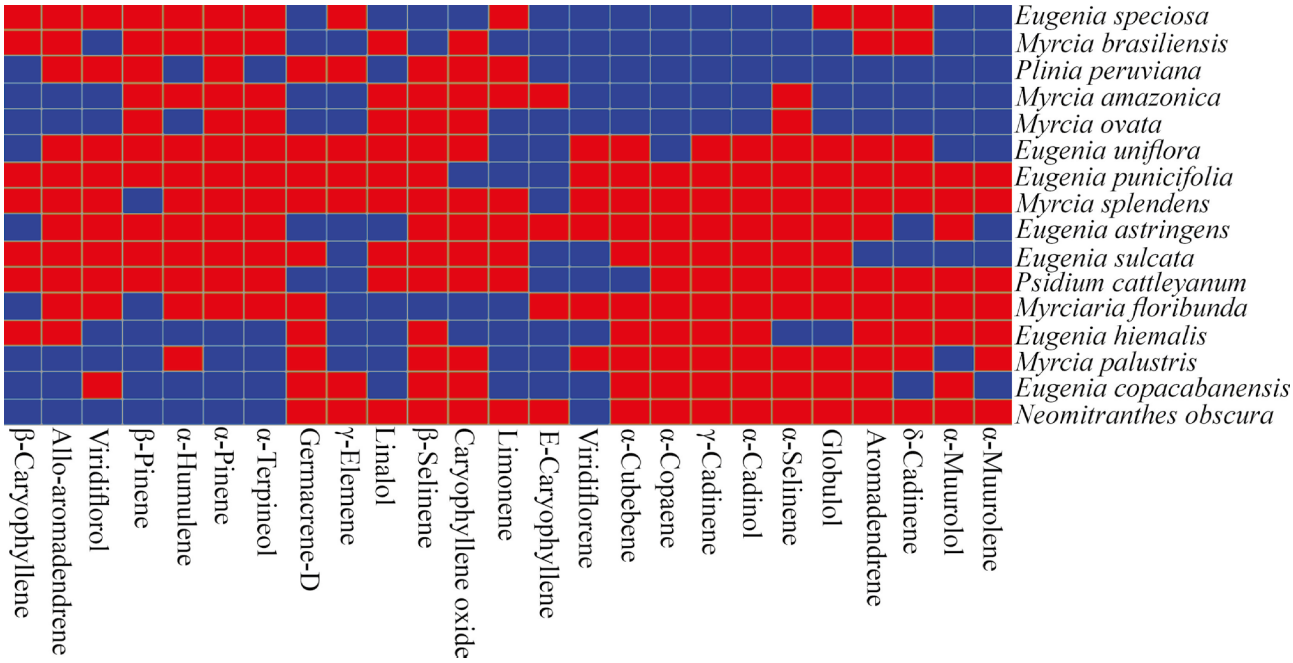

Figure 2. Absence and presence matrix of the most abundant chemical compounds per species. Red indicates presence; Blue indicates absence.

have the lowest distribution of compounds among the chemical subclasses (DV < 3). Regarding the highest percentages of chemical compounds in each class, *E. speciosa* has 42.3 % of MH, *M. ovata* has 56.6 % of OM, *E. hiemalis* has 60.8 % of SH, and *E. uniflora* has 42.8 % of OS. Regarding the lowest percentages of compounds per chemical class, *E. hiemalis* has 2.1 % of SH. *Eugenia hiemalis* and *M. palustris* have no OM, *M. amazonica* has 11.1 % of SH, and *P. peruviana* has 4.7 % of OS.

The heatmap revealed clear patterns in the abundance of chemical compounds per subclass among species. *Eugenia astringens*, *E. punicifolia, M. floribunda,* and *N. obscura* showed the highest variation and overall abundance in SH. The MH showed moderate abundance, with *E. astringens*, *E. speciosa,* and *M. floribunda* standing out among the group. The OS revealed intermediate variation, with higher values concentrated in *E. astringens* and *N. obscura*. In contrast, the OM exhibited consistently low values among most species, with a slight increase observed in *M. amazonica* (Fig. 3).

The case study of *Neomitranthes obscura*

Neomitranthes obscura has the third richest terpenoid profile among the 16 superhost Myrtaceae species analyzed herein, due to its diversity of hydrocarbon and oxygenated sesquiterpenes, sharing β-selinene, α-selinene, cariophylene oxide, aromadendrene, γ-cadinene, α-cadinol, globulol, α-copaene, germacrene D, α-cubebene, δ-cadinene, α-muurolol, limonene, α-muurolene, γ-elemene, and E-caryophyllene with the other species. However, seven compounds found in other Myrtaceae species have not been reported for *N. obscura*; these include α-pinene, β-pinene, α-humulene, α-terpineol, viridiflorol, linalool, and viridiflorene.

Regarding the phenolic compounds, the literature data indicate the chemical affinity of *N. obscura* to *Plinia peruviana*, which also contains delphinidin-3-O-glucoside. For *Psidium catleyanum,* both the sharing of cyanidin 3-O-glucoside and delphinidin-3-O-glucoside indicate higher chemical similarity. Nevertheless, the sesquiterpene profile of these three species is diverse, except for the SH. (Table 1). Additionally, *N. obscura* gall morphotypes show total phenolic compounds predominantly concentrated in the outer compartment tissues, while for the other host Myrtaceae species, the phenolics were detected all over gall tissues (Fig. 4).

Discussion

The analysis of the terpenoid profile of the studied species, based on literature data, indicated high heterogeneity. However, some compounds are shared by most of the species, indicating a certain affinity among them, such as *E. astringens, E. uniflora,* and *P. cattleyanum,* which demonstrates the richer diversity of volatile compounds in our survey. In Rio de Janeiro state, the superhosts of *restingas* with the highest number of distinct gall morphotypes reported are *E. uniflora* and *E. astringens* (Martins *et al.*, 2023), whose diversity of terpenoids includes limonene, E-caryophyllene, and γ-cadinene. The sesquiterpene hydrocarbon (E)-caryophyllene, for example, has even been

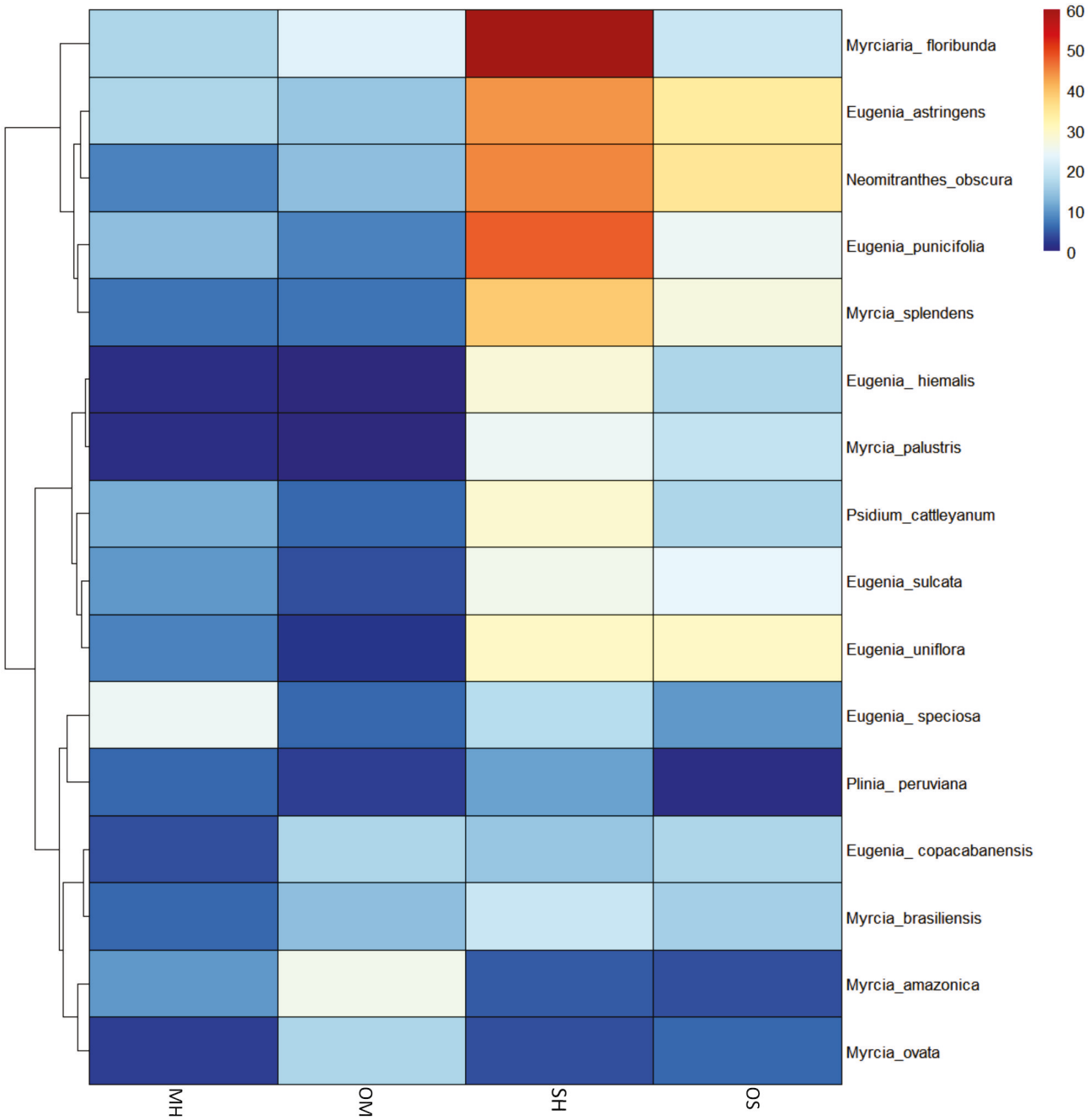

Figure 3. Distribution of chemical subclasses on Myrtaceae species. The heatmap illustrates the distribution of four classes: monoterpene hydrocarbons (MH), oxygenated monoterpenes (OM), sesquiterpene hydrocarbons (SH), and oxygenated sesquiterpenes (OS). Color key indicates chemical class expression value, blue: lowest, red: highest.

associated with stimulating the oviposition of *Orseolia oryzivora* (Cecidomyiidae) on *Oryza sativa* plants (Ogah *et al.*, 2017). Among the monoterpenes, alpha-pinene, beta-pinene, and limonene can be mentioned, which are involved in the attraction and oviposition of females of *Antistrophus rufus* (Hymenoptera) on *Silphium* (Asteraceae) (Tooker *et al.*, 2005), and increased γ-terpinene and α-pinene in *Eucalyptus* trees are also associated with the susceptibility of plants to *Leptocybe invasa* Fisher & La Salle (Hymenoptera) infestations (Naidoo *et al.*, 2018). On the other hand, the γ-cadinene is an early enzymatic intermediate in the biosynthesis of sesquiterpene phytoalexins (Tholl, 2015), and if these phytoalexins accumulate in the tissues of the hosts, this may activate the defense system, leading to hypersensitive responses and avoiding gall development (Fernandes, 1990). Besides that, the functions and mechanisms of action of phytoalexins are relatively unknown (Ahuja *et al.*, 2012), but some galls, like those induced on the *Parrotia subaequalis*

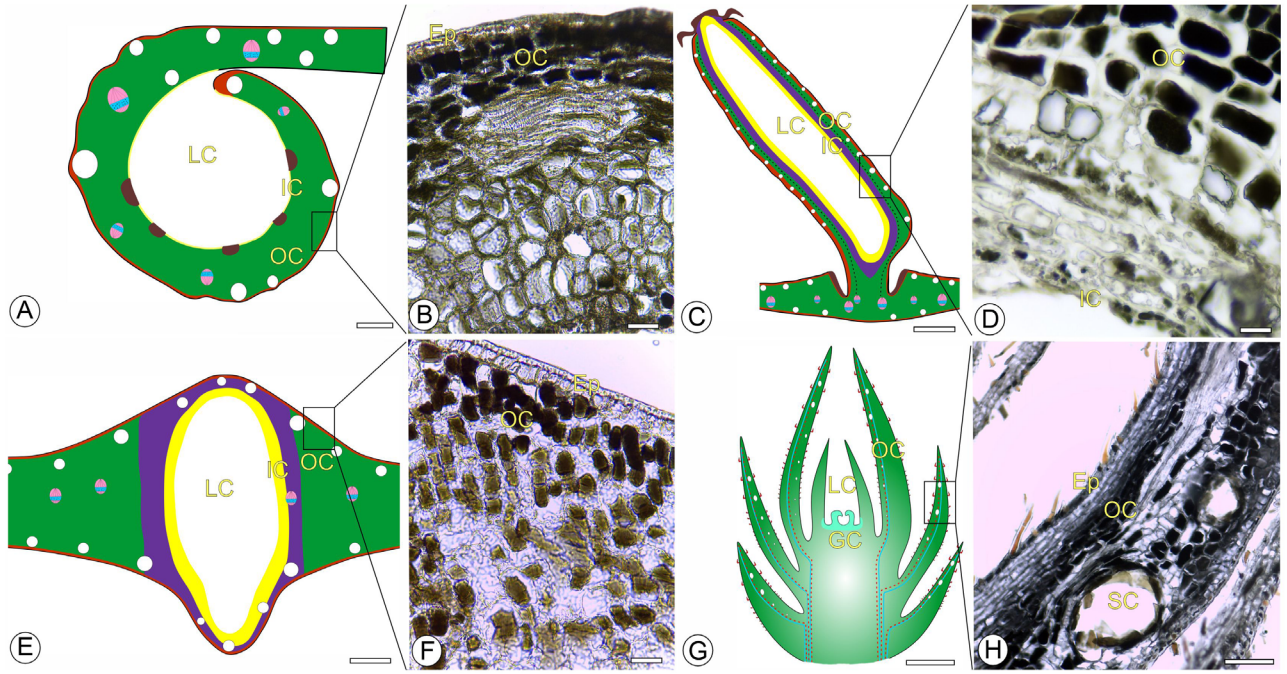

Figure 4. Histolocalization of phenolic compounds on *Neomitranthes obscura* (DC.) N. Silveira. **A-B** Marginal rolling gall. **A.** Diagram of the gall in transverse section. **B.** Detection of phenolic compounds on outer tissue compartment. **C-D.** Clavate gall. **C.** Diagram of the gall in transverse section. **D.** Concentration of phenolic compounds in the vacuole of outer tissue compartment layers. **E-F.** Lenticular gall. **E**. Diagram of the gall on transverse section, evidencing tissue organization. **F.** Detection of phenolic compounds on mesophyll layers. **G-H.** Bud gall. **G.** Diagram of the gall evidencing leaf primordia and leaf projections. **H.** Gall homogenous parenchyma with an accumulation of phenolics. (Ep=Epidermis; GC=Gall Core; IC=Inner Compartment; LC=Larval Chamber; OC=Outer Compartment; SC=Secretory Cavity). Scale bars: 500μm(G), 200μm (A, E), 50μm (B, D, H).

(H.T. Chang) R. M. Hao et H. T. Wei (Hamamelidaceae), accumulate different types of phytoalexins (Zhou *et al.*, 2025), indicating a possible role of these compounds in the establishment of galling species-host plant associations.

Despite belonging to distinct phylogenetic lineages (*sensu* Vasconcelos *et al.*, 2015), *N. obscura* exhibits a strong chemical similarity with *Plinia peruviana,* which may reflect convergent adaptive strategies or the conservation of biochemical traits within the tribe Myrteae (Padovan *et al.*, 2014). Notably, *E. astringens*, the species with the most diverse terpenoid profile, is one of the species with the most associated galls among Myrtaceae superhosts, with at least six galling insects associated, among those reported to Rio de Janeiro State (Martins *et al.*, 2023). When we compared the association species-terpenoid profile, we can observe a tendency toward diversity in the terpenoid profile (expressed in SH and OS), especially in superhost species (Fig. 3) when compared to the other species, except for *M. ovata* and *E. copacabanensis*. Therefore, we can associate the diversity of terpenoids types with the richness of associated gall inducers. The metabolic diversity of the superhosts may indicate that they are more able to respond to biotic interactions, possibly altering their biochemical pathways, which is yet to be explored.

One of the most common chemical compounds, β-selinene, which is reported in most species, is known for its allelopathic effects (Bewick *et al.*, 1994). Recently, the joint effects of herbivory and allelopathy on driving the diversity–invasibility relationship were proposed in a 2-year experiment, providing a perspective for future studies (Wang *et al.*, 2025). Beyond its allelopathic potential, β-selinene-derived products are associated with defense-promoting mechanisms in model plants, like maize, against fungi and some insects (Ding *et al.*, 2017); however, they may also act in the attraction of plant-parasitic nematodes (Ali *et al.*, 2011). In our review, we have not found the occurrence of galls induced by nematodes in the Myrtaceae species; however the preponderance of β-selinene in most superhosts may indicate the occurrence of trade-offs between plant defense and herbivore attraction by this chemical group, in a similar way as the DIMBOA metabolites in grasses, which were previously indicated as a potential mechanism to understand host-galler associations (Arriola *et al.*, 2024). It is reinforced by its relationship with smell emissions by some insects (Sakurai *et al.*, 2020). Other chemical compounds like β-pinene, α-terpineol, allo-aromadendrene, γ-cadinene, α-cadinol, and globulol are very common in the superhost Myrtaceae analyzed herein, despite their insect repellent effects (Mya *et al.*, 2017). The α-terpineol and

alloaromadendrene exhibit antioxidant effects (Chen *et al.*, 2023; Yu *et al.*, 2014), which may mitigate the impact of excess reactive oxygen species commonly found in the gall tissue environment, resulting from the high metabolism of the galling larvae and plant cells. Such compounds may be of metabolic interest for the superhost Myrtaceae and other taxa associated with several gall-inducing species, which have yet to be evaluated.

Regarding the volatile components, chemical data revealed the prevalence of non-oxygenated terpenoids, with a greater diversity among sesquiterpenes, which can be chemotaxonomic markers for these superhost taxa within the Myrtaceae. The sesquiterpenes tend to be semivolatile due to oxygenation. From a biological activity perspective, the low oxygenation of the components of the mono- and sesquiterpenes is related to their high volatility. Volatile terpenoids possess a series of signaling properties whose role in host selection has been observed in insects, including those from galling taxonomic groups. There is still little research on the importance of terpenoids in attracting gall inducers. These metabolites may play a key role in host plant selection by gall inducers (Tooker *et al.*, 2008).

Although phenolics are highly important in host plant-galling insect systems, few studies on the superhost Myrtaceae have isolated such a group of chemical compounds. The histochemical analysis of non-galled and galls on *N. obscura* confirmed the intense accumulation of phenolic compounds. In general, these phenolic metabolites, such as simple derivatives (gallic acid and cinnamic acids), gallic and condensed tannins, and monomeric flavonoids, play a key role in redox balance, which may favor galler establishment (Ferreira *et al.*, 2018; Guedes *et al.*, 2019; 2022). However, the data presented here do not reveal any discernible patterns related to superhosts. Future studies could compare host and non-host Myrtaceae species in *restingas* to assess whether superhosts exhibit quantitative or qualitative differences in phenolic compounds.

The metabolite profile of Myrtaceae superhosts reveals chemotaxonomic similarities, yet no obvious pattern fully explains their role as gall superhosts. Several Myrtaceae superhosts possess a wide range of hydrogenated sesquiterpenes and oxygenated sesquiterpenes, differentiating them from other hosts, although this is not a rule. Many of the substances produced by Myrtaceae superhosts, particularly mono- and sesquiterpenoids, may function as chemical signals for gall-inducing herbivores. The fact that these plants are related and emit chemically similar volatile signals may provide clues to unraveling the mystery of superhosts. Further chemoecological studies involving the effects of specific volatile signal emissions on galling species of these Myrtaceae are needed. A remaining question is why certain Myrtaceae species host diverse galling herbivores while closely related species do not? To address this, further chemical studies should investigate how specific volatile emissions influence galling insect preferences and colonization in these plants.

Acknowledgments

The authors thank the Researchers of the "Structure, Physiology and Chemistry of Neotropical Galls" team for field support and scientific discussions that enriched the final version of the manuscript.

Authors' Contributions

MAMR and CVCG: conceptualization, data curation, formal analysis, methodology, visualization, writing – original draft, review and editing; ÍAA and GLGS: formal analysis, writing – original draft, review and editing; RMSI and BGF: conceptualization, supervision, funding acquisition, project administration, resources, writing – review and editing.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Data Availability

All data supporting the findings of this study are included in the article.

Funding Information

The authors thank Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) for financial support, scholarship to MAMR and postdoctoral fellowship to ÍAA (RED-00039-23), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for RMSI (309713/2023-4) and BGF (310520/2023-1) scholarships and grants, and Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) for project support to BGF (E-26/204.608/2024; E-26/210.586/2025).

References

Adam F, Vahirua-Lechat I, Deslandes E, Menut C. 2011. Aromatic plants of French Polynesia. V. Chemical composition of essential oils of leaves of *Psidium guajava* L. and *Psidium cattleyanum* Sabine. Journal of Essential Oil Research 23: 98-101.

Ahuja I, Kissen R, Bones AM. 2012. Phytoalexins in defense against pathogens. Trends in Plant Science 17: 73-90.

Ali JG, Alborn HT, Stelinski LL. 2011. Constitutive and induced subterranean plant volatiles attract both entomopathogenic and plant parasitic nematodes. Journal of Ecology 99: 26-35.

Almeida CJR, Donadel G, Dalmagro M *et al.* 2025. Polymeric film loaded with *Plinia cauliflora* peels extract has a differential curative effect on injuries. Journal of Pharmaceutical Innovation 20: 23.

Alves LV, Alegrio LV, Castro RN, Oliveira Godoy RLD. 2000. Essential oil of *Eugenia speciosa* Camb. (Myrtaceae) from Rio de Janeiro, Brazil. Journal of Essential Oil Research 12: 693-694.

Alves MF, Castro NDA, Sampaio TS *et al.* 2016. *Myrcia lundiana* Kiaersk native populations have different essential oil composition and antifungal activity against *Lasiodiplodia theobromae*. Industrial Crops and Products 85: 266-273.

Amaral RR, Fernandes CP, Caramel OP *et al.* 2013. Essential oils from fruits with different colors and leaves of *Neomitranthes obscura* (DC.) N. Silveira: An endemic species from Brazilian Atlantic Forest. BioMed Research International 2013: 723181.

Amorim BS, Alves M. 2012. Myrtaceae from lowland Atlantic Forest areas in the state of Pernambuco, Northeastern Brazil. Phytotaxa 40: 33-54.

Apel MA, Sobral M, Schapoval EE, Henriques AT, Menut C, Bessiere JM. 2004. Chemical composition of the essential oils of *Eugenia hyemalis* and *Eugenia stigmatosa*. Part VI: section Biflorae. Journal of Essential Oil Research 16: 437-439.

Apel MA, Limberger RP, Sobral M *et al.* 2002. Chemical composition of the essential oils from southern Brazilian *Eugenia* species. Part III. Journal of Essential Oil Research 14: 259-262.

Araújo ES, Mota GS, Lorenço MS *et al.* 2020. Characterisation and valorisation of the bark of *Myrcia eximia* DC. trees from the Amazon rainforest as a source of phenolic compounds. Holzforschung 74: 989-998.

Arriola ÍA, Costa EC, Oliveira DC, Isaias RMS. 2024. Soil–plant–gall relationships: from gall development to ecological patterns. Biological Reviews 99: 1948-1975.

Arruda RDC, Victório CP. 2011. Leaf secretory structure and volatile compounds of *Eugenia copacabanensis* Kiaersk. (Myrtaceae). Journal of Essential Oil Research 23: 1-6.

Bedetti CS, Bragança GP, Isaias RMS. 2017. Influence of auxin and phenolic accumulation on the patterns of cell differentiation in distinct gall morphotypes on *Piptadenia gonoacantha* (Fabaceae). Australian Journal of Botany 65: 411-420.

Bedetti CS, Jorge NC, Trigueiro FCG, Bragança GP, Modolo LV, Isaias RMS. 2018. Detection of cytokinins and auxin in plant tissues using histochemistry and immunocytochemistry. Biotechnic & Histochemistry 93: 149-154.

Bewick TA, Shilling DG, Dusky JA, Willians D. 1994. Effects of Celery (*Apium graveolens*) Root Residue on Growth of Various Crops and Weeds. Weed Technology 8: 625-629.

Bokesch HR, Wamiru A, Le Grice SF, Beutler JA, McKee TC, McMahon JB. 2008. HIV-1 ribonuclease H inhibitory phenolic glycosides from *Eugenia hyemalis*. Journal of Natural Products 71: 1634-1636.

Boulet M, Crawford JC, Charpentier MJE, Drea CM. 2010. Honest olfactory ornamentation in a female-dominant primate. Journal of Evolutionary Biology 23: 1558-1563.

Borges RM. 2018. The galling truth: Limited knowledge of gall-associated volatiles in multitrophic interactions. Frontiers in Plant Science 9: 1139.

Carvalho-Junior ARD, Gomes GA, Ferreira RO, Carvalho MGD. 2014. Chemical constituents and antioxidant activity of leaves and branches of *Eugenia copacabanensis* Kiaersk (Myrtaceae). Química Nova 37: 477-482.

Chao A, Chiu CH, Jost L. 2014. Unifying species diversity, phylogenetic diversity, functional diversity, and related similarity and differentiation measures through Hill numbers. Annual Review of Ecology, Evolution, and Systematics 45: 297-324.

Chen Y, Zhang LL, Wang W, Wang G. 2023. Recent updates on bioactive properties of α-terpineol. Journal of Essential Oil Research 35: 274-288.

Cole RA, Haber WA, Setzer WN. 2008. The leaf oil composition of *Myrcia splendens* from Monteverde, Costa Rica. Journal of Essential Oil Bearing Plants 11: 41-44.

Defaveri AC, Sato A, Borré LB *et al.* 2011. *Eugenia neonitida* Sobral and *Eugenia rotundifolia* Casar. (Myrtaceae) essential oils: Composition, seasonality influence, antioxidant activity and leaf histochemistry. Journal of the Brazilian Chemical Society 22: 1531-1538.

Ding Y, Huffaker A, Köllner TG *et al.* 2017. Selinene volatiles are essential precursors for maize defense promoting fungal pathogen resistance. Plant Physiology 175: 1455-1468.

Divekar PA, Narayana S, Divekar BA *et al.* 2022. Plant secondary metabolites as defense tools against herbivores for sustainable crop protection. International Journal of Molecular Sciences 23: 2690.

El-Deeb EM, Elsayed HE, Ateya HB *et al.* 2024. Phenolic profiling and bioactivity assessment of in vitro propagated *Psidium cattleianum* Sabine: A promising study. Heliyon 10: e26113.

Fernandes, GW. 1990. Hypersensitivity: A neglected plant resistance mechanism against insect herbivores. Environmental Entomology 19: 1173-1182.

Ferreira AC, Neto JC, Silva AC, Kuster RM, Carvalho DP. 2006. Inhibition of thyroid peroxidase by *Myrcia uniflora* flavonoids. Chemical Research in Toxicology 19: 351-355.

Ferreira BG, Oliveira DC, Moreira AS *et al.* 2018. Antioxidant metabolism in galls due to the extended phenotypes of the associated organisms. PLoS One 13: e0205364.

Flora e Funga do Brasil. 2025. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/. 20 Jul. 2025.

Ferreira BG, Álvarez R, Bragança GP, Alvarenga DR, Pérez-Hidalgo N, Isaias RMS. 2019. Feeding and other gall facets: Patterns and determinants in gall structure. Botanical Review 85: 78-106.

García YM, Lemos EEPD, Augusti R, Melo JOF. 2021. Optimization of extraction and identification of volatile compounds from *Myrciaria floribunda*. Revista Ciência Agronômica 52: e20207199.

García YM, Ramos ALCC, Nunes BV *et al.* 2022. Caracterização fisico-química e perfil de compostos voláteis de frutos de diferentes acessos de *Myrciaria floribunda* utilizando a microextração em fase sólida. In: Melo JOF (org.). Ciências Agrárias: o avanço da ciência no Brasil. Guarujá/São Paulo, Editora Científica Digital, vol. III, p. 101-123.

Giaretta A, Peixoto AL. 2015. Myrtaceae da restinga no norte do Espírito Santo, Brasil. Boletim do Museu de Biologia Mello Leitão (Nova Série) 37: 45-126.

Girardelo JR, Munari EL, Dallorsoleta JC *et al.* 2020. Bioactive compounds, antioxidant capacity and antitumoral activity of ethanolic extracts from fruits and seeds of *Eugenia involucrata* DC. Food Research International 137: 109615.

Godoy RL, Alegrio LV, Duarte AA. 1999. Compositional analysis of the leaf oil of *Eugenia ovalifolia* Camb. (Myrtaceae). Journal of Essential Oil Research 11: 570-572.

Gouvêa ACM, Melo A, Santiago MC *et al.* 2015. Identification and quantification of anthocyanins in fruits from *Neomitranthes obscura* (DC.) N. Silveira, an endemic species from Brazil, by comparison of chromatographic methodologies. Food Chemistry 185: 277-283.

Govaerts R, Sobral M, Ashton P *et al.* 2019. World Checklist of Myrtaceae. Royal Botanic Gardens, Kew Publishing.

Grandez-Rios JM, Araújo WS, Panduro-Bardales A *et al.* 2024. Plant species richness, not hygrothermal stress, is the main predictor of gall-inducing insect richness in Peruvian Amazon forests. Biotropica 56: e13312.

Guedes LM, Aguilera N, Becerra J, Hernández V, Isaias RMS. 2016. Leaf and stem galls of *Schinus polygamus* (Cav.) Cabr. (Anacardiaceae): Anatomical and chemical implications. Biochemical Systematics and Ecology 69: 266-273.

Guedes LM, Aguilera N, Ferreira BG *et al.* 2019. Spatiotemporal variation in phenolic levels in galls of calophyids on *Schinus polygama* (Anacardiaceae). Journal of Plant Research 132: 509-520.

Guedes LM, Torres S, Sáez-Carillo K, Becerra J, Pérez CI, Aguilera N. 2022. High antioxidant activity of phenolic compounds dampens oxidative stress in *Espinosa nothofagi* galls induced on *Nothofagus obliqua* buds. Plant Science 314: 111114.

Guedes LM, Gavilán E, Pérez C, Becerra J, Aguilera N. 2023. Impact of the galling *Dasineura* sp. on the structural and chemical profile of *Peumus boldus* stems. Trees 37: 545-553.

Guldbrandsen N, Mieri M, Gupta M *et al.* 2014. Screening of Panamanian plant extracts for pesticidal properties and HPLC-based identification of active compounds. Scientia Pharmaceutica 83: 353.

Hall CR, Carroll AR, Kitching RL. 2017. A meta-analysis of the effects of galling insects on host plant secondary metabolites. Arthropod-Plant Interactions 11: 463-473.

Hammer O, Harper DAT, Ryan PD. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4: 1-9.

Hilker M. 2014. New synthesis: Parallels between biodiversity and chemodiversity. Journal of Chemical Ecology 40: 225-226.

Holopainen JK, Himanen SJ, Yuan JS, Chen F, Stewart CN. 2013. Ecological functions of terpenoids in changing climates. In: Ramawat KG, Mérillon JM (eds.). Natural Products. Berlin/Heidelberg, Springer, p. 2913-2940.

Inada KO, Torres AG, Perrone D, Monteiro M. 2018. High hydrostatic pressure processing affects the phenolic profile, preserves sensory attributes and ensures microbial quality of jabuticaba (*Myrciaria jaboticaba*) juice. Journal of the Science of Food and Agriculture 98: 231-239.

Isaias RMS, Carneiro RGS, Oliveira DC, Santos JC. 2013. Illustrated and annotated checklist of Brazilian gall morphotypes. Neotropical Entomology 42: 230-239.

Isaias RMS, Ferreira BG, Alvarenga DR, Barbosa LR, Salminen JP, Steinbauer MJ. 2018. Functional compartmentalization of nutrients and phenolics in the tissues of galls induced by *Leptocybe invasa* (Hymenoptera: Eulophidae) on *Eucalyptus camaldulensis* (Myrtaceae). Austral Entomology 57: 238-246.

Isaias RMS, Oliveira DC, Moreira ASFP, Soares GL, Carneiro RGS. 2015. The imbalance of redox homeostasis in arthropod-induced plant galls: Mechanisms of stress generation and dissipation. Biochimica et Biophysica Acta - General Subjects 1850: 1509-1517.

Johansen DA. 1940. Plant Microtechnique. New York, McGraw-Hill Book Company.

Jorge NC, Souza-Silva ÉA, Alvarenga DR *et al.* 2018. Structural and chemical profiles of *Myrcia splendens* (Myrtaceae) leaves under the influence of the galling *Nexothrips* sp. (Thysanoptera). Frontiers in Plant Science 9: 1521.

Jost L. 2006. Entropy and diversity. Oikos 113: 363-375.

Karnovsky MJ. 1965. A formaldehyde-glutaraldehyde fixative of high osmolality for use in electron-microscopy. Journal of Cell Biology 27: 137-138.

Keszei A, Brubaker CL, Carter R, Köllner T, Degenhardt J, Foley WJ. 2010. Functional and evolutionary relationships between terpene synthases from Australian Myrtaceae. Phytochemistry 71: 844-852.

Kolde R. 2019. pheatmap: Pretty Heatmaps. https://CRA.R-project.org/package=pheatmap. Accessed on 18 July 2025 Lima BG, Tietbohl LA, Fernandes CP *et al.* 2012. Chemical composition of essential oils and anticholinesterasic activity of *Eugenia sulcata* Spring ex Mart. Latin American Journal of Pharmacy 31: 152-155.

Lima MA, Oliveira FFM, Gomes GA *et al.* 2011. Evaluation of larvicidal activity of the essential oils of plants species from Brazil against *Aedes aegypti* (Diptera: Culicidae). African Journal of Biotechnology 10: 11716-11720.

Limberger RP, Simões-Pires CA, Sobral M, Menut C, Bessiere JM, Henriques AT. 2003. Essential oils of six *Gomidesia* spp. from southern Brazil. Flavour and Fragrance Journal 18: 144-147.

Lourenço ARL, Barbosa MR. 2012. Myrtaceae em restingas no limite norte de distribuição da Mata Atlântica, Brasil. Rodriguésia 63: 373-393.

Mabberley DJ. 1997. The Plant-Book. 2nd. edn. Cambridge, Cambridge University Press.

Magina MD, Dalmarco EM, Wisniewski Jr A *et al.* 2009. Chemical composition and antibacterial activity of essential oils of *Eugenia* species. Journal of Natural Medicines 63: 345-350.

Maia JG, Zoghbi MDG, Luz AI. 1997. Essential oil of *Eugenia punicifolia* (HBK) DC. Journal of Essential Oil Research 9: 337-338.

Maia VC. 2013. Galhas de insetos em restingas da região sudeste do Brasil com novos registros. Biota Neotropica 13: 183-209.

Maia VC. 2019. Insect galls on Myrtaceae: Richness and distribution in Brazilian restingas. Biota Neotropica 19: e20180526.

Maia VC. 2024. Gall-inducing insects from the Maricá Environmental Protection Area (RJ, Southeastern Brazil). Revista Brasileira de Entomologia 68: e20230086.

Maia VC, Carvalho-Fernandes S, Rodrigues AR, Ascendino S. 2014. Galls in the Brazilian Coastal Vegetation. In: Fernandes GW, Santos JC (eds.). Neotropical Insect Galls. Dordrecht, Springer, p. 197-221.

Marin R, Apel MA, Limberger RP *et al.* 2008. Volatile components and antioxidant activity from some Myrtaceous fruits cultivated in Southern Brazil. Latin American Journal of Pharmacy 27: 172.

Martins GS, Nobrega LP, Castro RR *et al.* 2023. Who are the superhosts? The chemical and structural profiles of superhosts of galling arthropods and the gaps in gall studies. Arthropod-Plant Interactions 17: 705-740.

Martins LR, Sampaio PSP, Magenta MAG. 2008. Caracterização florística de comunidades vegetais de restinga em Bertioga, SP, Brasil. Acta Botanica Brasilica 22: 249-274.

Melo RM, Corrêa VF, Amorim ACL, Miranda ALP, Rezende CM. 2007. Identification of impact aroma compounds in *Eugenia uniflora* L. (Brazilian Pitanga) leaf essential oil. Journal of the Brazilian Chemical Society 18: 179-183.

Mesquita PR, Nunes EC, Santos FN *et al.* 2017. Discrimination of *Eugenia uniflora* L. biotypes based on volatile compounds in leaves using HS-SPME/GC–MS and chemometric analysis. Microchemical Journal 130: 79-87.

Montalvão MM, Felix FB, Santos EWP *et al.* 2023. Cytotoxic activity of essential oil from leaves of *Myrcia splendens* against A549 lung cancer cells. BMC Complementary Medicine and Therapies 23: 139.

Mya M, Aung ZZ, Nwe C *et al.* 2017. Larvicidal, ovicidal and repellent effect of *Citrus hystrix* DC. (Kaffir lime) fruit, peel and internal materials extracts on *Aedes aegypti* mosquitoes. Journal of Biological Engineering Research and Review 4: 34-43.

Naidoo S, Christie N, Acosta JJ, Mphahlele MM, Payn KG, Myburg AA, Külheim C. 2018. Terpenes associated with resistance against the gall wasp, *Leptocybe invasa*, in *Eucalyptus grandis*. Plant, Cell & Environment 41: 1840-1851.

Nakamura MJ, Monteiro SS, Bizarri CH, Siani AC, Ramos MF. 2010. Essential oils of four Myrtaceae species from the Brazilian southeast. Biochemical Systematics and Ecology 38: 1170-1175.

Neves KO, Santos MF, Mar JM *et al.* 2024. ^{1}H NMR chemical profile and antioxidant activity of *Eugenia punicifolia* extracts over seasons: A metabolomic pilot study. Journal of the Brazilian Chemical Society 35: e-20240010.

Ogah EO, Smart LE, Woodcock CM *et al.* 2017. Electrophysiological and behavioral responses of female African rice gall midge, *Orseolia oryzivora* Harris and Gagné, to host plant volatiles. Journal of Chemical Ecology 43: 13-16.

Oksanen J, Simpson G, Blanchet F *et al.* 2022. vegan: Community Ecology Package. R package version 2.6-4. https://CRAN.R-project.org/package=vegan. 18 July 2025.

Oliveira AMD, Humberto MMS, Silva JM, Rocha RFA, Sant'Ana AEG. 2006. Estudo fitoquímico e avaliação das atividades moluscicida e larvicida dos extratos da casca do caule e folha de *Eugenia malaccensis* L. (Myrtaceae). Revista Brasileira de Farmacognosia 16: 618-624.

Oliveira DC, Christiano JC, Soares GLG, Isaias RMS. 2006. Reações de defesas químicas e estruturais de *Lonchocarpus muehlbergianus* Hassl. (Fabaceae) à ação do galhador *Euphalerus ostreoides* Crawf. (Hemiptera: Psyllidae). Brazilian Journal of Biology 29: 657-667.

Oliveira DC, Isaias RMS, Fernandes GW, Ferreira BG, Carneiro RGS, Fuzaro L. 2016. Manipulation of host plant cells and tissues by gall-inducing insects and adaptive strategies used by different feeding guilds. Journal of Insect Physiology 84: 103-113.

Oliveira RN, Dias IJ, Câmara CA. 2005. Estudo comparativo do óleo essencial de *Eugenia punicifolia* (HBK) DC. de diferentes localidades de Pernambuco. Revista Brasileira de Farmacognosia 15: 39-43.

Oliveira LM, Porte A, Oliveira GRL *et al.* 2018. Chemical characterization of *Myrciaria floribunda* (H. West ex Willd) fruit. Food Chemistry 248: 247-252.

Padovan A, Keszei A, Külheim C, Foley WJ. 2014. The evolution of foliar terpene diversity in Myrtaceae. Phytochemistry Reviews 13: 695-716.

Papoutsis K, Zhang J, Bowyer MC, Brunton N, Gibney ER, Lyng J. 2021. Fruit, vegetables, and mushrooms for the preparation of extracts with α-amylase and α-glucosidase inhibition properties: A review. Food Chemistry 338: 128119.

Pereira RA, Zoghbi MDGB, Bastos MDNC. 2010. Essential oils of twelve species of Myrtaceae growing wild in the sandbank of the Resex Maracanã, State of Pará, Brazil. Journal of Essential Oil Bearing Plants 13: 440-450.

Pereira-Júnior RC. 2018. Caracterização química e avaliação dos potenciais antimicrobiano, inseticida e citotóxico de óleos essenciais obtidos de *Myrcia* spp. (Myrtaceae) ocorrentes em ecossistema de terra firme (Amazônia). PhD Thesis, Universidade Federal do Amazonas, Brazil.

Pino JA, Bello A, Urquiola A, Aguero J, Marbot R. 2003. Leaf Oils of *Psidium cymosum* Urb. and *Psidium sartorianum* Niedz. from Cuba. Journal of Essential Oil Research 15: 187-188.

Pino JA, Marbot R, Payo A, Chao D, Herrera P, Martí MP. 2005. Aromatic plants from Western Cuba. I. Composition of leaf oil of *Gymnanthes lucida* Sw. and *Eugenia rhombea* (Berg) Krug *et* Urban. Journal of Essential Oil Research 17: 278-280.

Pinto GM, Succar JB, Victorio CP, Assis MC. 2022. Plant volatiles from the Brazilian restinga with bactericidal activity against multiresistant bacteria. Concilium 22: 598-612.

Posit Team. 2025. RStudio: Integrated Development Environment for R. http://www.posit.co/. 18 July 2025.

Queiroz JMG, Suzuki MCM, Motta APR, Nogueira JMR, Carvalho EM. 2015. Aspectos populares e científicos do uso de espécies de *Eugenia* como fitoterápico. Revista Fitos 9: 87-100.

Ramirez MR, Schnorr CE, Feistauer LB *et al.* 2012. Evaluation of the polyphenolic content, anti-inflammatory and antioxidant activities of total extract from *Eugenia pyriformes* Cambess (Uvaia) fruits. Journal of Food Biochemistry 36: 405-412.

Ramos MFDS, Monteiro SDS, Silva VP, Nakamura MJ, Siani AC. 2010. Essential oils from Myrtaceae species of the Brazilian Southeastern maritime forest (Restinga). Journal of Essential Oil Research 22: 109-113.

Ribeiro PH, Santos MLD, Camara CAD, Born FS, Fagg CW. 2016. Seasonal chemical compositions of the essential oils of two *Eugenia* species and their acaricidal properties. Química Nova 39: 38-43.

Rodrigues KAF, Amorim LV, Oliveira JMGD *et al.* 2013. *Eugenia uniflora* L. essential oil as a potential anti-leishmania agent: Effects on *Leishmania amazonensis* and possible mechanisms of action. Evidence-Based Complementary and Alternative Medicine 2013: 279726.

Roininen H, Price PW, Julkunen-Tiitto R, Tahvanainen J, Ikonen A. 1999. Oviposition stimulant for a gall-inducing sawfly, *Euura lasiolepis*, on willow is a phenolic glucoside. Journal of Chemical Ecology 25: 943-953.

Rosario AS, Secco RC, Amaral DD, Santos JUM, Bastos MNC. 2005. Flórula fanerogâmica das restingas do Estado do Pará. Ilhas do Algodoal e Maiandeua. Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais 1: 31-48.

Rostás M, Maag D, Ikegami M, Inbar M. 2013. Gall volatiles defend aphids against a browsing mammal. BMC Evolutionary Biology 13: 193.

Saber FR, Munekata PE, Rizwan K *et al.* 2023. Family Myrtaceae: The treasure hidden in the complex/diverse composition. Critical Reviews in Food Science and Nutrition 64: 6737-6755.

Sakurai K, Tomiyama K, Yaguchi Y, Asakawa Y. 2020. The characteristic smell emitted from two scale insects, *Ceroplastes japonicus* and *Ceroplastes rubens*. Bioscience, Biotechnology, and Biochemistry 84: 1541-1545.

Santos FR, Braz-Filho R, Castro RN. 2015. Influence of age of the leaves of *Eugenia uniflora* L. on chemical composition of essential oil. Química Nova 38: 762-768.

Santos CV, Malmann AP, Toledo AG *et al.* 2021. Chemical composition, antimicrobial and antioxidant activity of leaves essential oil the *Myrcia palustris* DC. (MYRTACEAE). Research, Society and Development 10: e20510313303.

Santos JFS, Rocha JE, Bezerra CF *et al.* 2018. Chemical composition, antifungal activity and potential anti-virulence evaluation of the *Eugenia uniflora* essential oil against *Candida* spp. Food Chemistry 261: 233-239.

Santos MPG, Silva SIB, Silva VBG *et al.* 2023. Essential oil from leaves of *Myrciaria floribunda* (H. West ex Willd.) O. Berg has antinociceptive and anti-inflammatory potential. Inflammopharmacology 31: 3143-3151.

Santos PVL, Nazaré SE, Sousa Barroso A *et al.* 2022. Chemometric analysis of the seasonal variation in the essential oil composition of *Psidium acutangulum* growing in the Brazilian Amazon. Biochemical Systematics and Ecology 105: 104528.

Silva APG, Spricigo PC, Purgatto E, Alencar SM, Jacomino AP. 2019. *Plinia trunciflora* and *Plinia cauliflora*: Two species rich in bioactive compounds, terpenes, and minerals. Journal of Food Measurement and Characterization 13: 921-931.

Silva DS, Pinto LA, Keller LAM *et al.* 2024. Inhibitory potential of *Eugenia sulcata* essential oil and its nanoemulsions against *Aspergillus* spp. Journal of Natural Pesticide Research 7: 100064.

Silva PR, Mendonça HDOP, Nogueira LA *et al.* 2021. Avaliação biométrica e físico-química e estudo do perfil químico da *Eugenia dysenterica*. In: Melo JOF (org.). Ciências Agrárias: o avanço da ciência no Brasil. Guarujá/São Paulo, Editora Científica, p. 367-388.

Silva TD, Souza MT, Souza MT, Cipriano RR, Bizzo HR, Deschamps C. 2021. Essential oil content and chemical composition in 14 selected species from a stretch of restinga in Southern Brazil. Journal of Agricultural Science 13: 23.

Souza AP, Oliveira DC, Dalvi VC, Kuster VC. 2024. Nutritive tissue rich in reserves in the cell wall and protoplast: The case of *Manihot esculenta* (Euphorbiaceae) galls induced by *Iatrophobia brasiliensis* (Diptera, Cecidomyiidae). Protoplasma 261: 513-525. doi: 10.1007/s00709-023-01878-2

Souza MC, Morim MP. 2008. Subtribos Eugeniinae O. Berg e Myrtinae O. Berg (Myrtaceae) na Restinga da Marambaia, RJ, Brasil. Acta Botanica Brasilica 22: 249-274.

Stefanello MÉA, Cervi AC, Wisniewski Jr A, Simionatto EL. 2010. Composição e variação sazonal do óleo essencial de *Myrcia obtecta* (O. Berg) Kiaersk. var. *obtecta*, Myrtaceae. Revista Brasileira de Farmacognosia 20: 82-86.

Stehmann JR, Forzza RC, Sobral M, Kamino LHY. 2009. Gimnospermas e Angiospermas. In: Stehmann JR, Forzza RC, Salino A, Sobral M, Costa DP, Kamino LHY (eds.). Plantas da Floresta Atlântica. Rio de Janeiro, pp. 27-37.

Tholl D. 2015. Biosynthesis and biological functions of terpenoids in plants. Advances in Biochemical Engineering/Biotechnology 148: 63-106.

Toffolatti SL, Maddalena G, Passera A, Casati P, Bianco PA, Quaglino F. 2021. Role of terpenes in plant defense to biotic stress. In: Jogaiah S (ed.). Biocontrol Agents and Secondary Metabolites. Woodhead Publishing, p. 401-417.

Tooker JF, Crumrin AL, Hanks LM. 2005. Plant volatiles are behavioral cues for adult females of the gall wasp *Antistrophus rufus*. Chemoecology 15: 85-88.

Tooker JF, Rohr JR, Abrahamson WG, De Moraes CM. 2008. Gall insects can avoid and alter indirect plant defenses. New Phytologist 178: 657-671.

Valterová I, Nehlin G, Borg-Karlson AK. 1997. Host plant chemistry and preferences in egg-laying *Trioza apicalis* (Homoptera: Psylloidea). Biochemical Systematics and Ecology 25: 477-491.

Vasconcelos TN, Prenner G, Bünger MO, Carvalho PS, Wingler A, Lucas EJ. 2015. Systematic and evolutionary implications of stamen position in Myrteae (Myrtaceae). Botanical Journal of the Linnean Society 179: 388-402.

Victório CP, Azevedo AC, Silveira EG *et al.* 2018. Leaf essential oils and volatiles, histochemistry and micromorphology of *Neomitranthes obscura* (DC.) N. Silveira (Myrtaceae) growing in sandy coastal plains of Rio de Janeiro. Biochemical Systematics and Ecology 78: 66-76.

Wang J, Gao S, Hong H *et al.* 2025. Herbivory and allelopathy contribute jointly to the diversity–invasibility relationship. Ecology 106: e4490.

Yang L, Wang X, Hou A *et al.* 2021. A review of the botany, traditional uses, phytochemistry, and pharmacology of the *Flos Inulae*. Journal of Ethnopharmacology 276: 114125.

Yu CW, Li WH, Hsu FL, Yen PL, Chang ST, Liao VHC. 2014. Essential oil alloaromadendrene from mixed-type *Cinnamomum osmophloeum* leaves prolongs the lifespan in *Caenorhabditis elegans*. Journal of Agricultural and Food Chemistry 62: 6159-6165.

Zatelli GA. 2015. Investigação fitoquímica e biológica de *Eugenia hiemalis* Cambessèdes (Myrtaceae). PhD Thesis, Universidade Federal do Rio de Janeiro, Brazil.

Zhou PJ, Wu XY, Zhao ZY *et al.* 2025. Benzofurans and dibenzofurans from galls on twigs of the endangered Chinese endemic tree *Parrotia subaequalis* and their inhibitory properties against *Staphylococcus aureus* and ATP-citrate lyase. Phytochemistry 229: 114309.